CLAIMS

1. A converging element which converges a light beam from a light source onto each of at least two types of optical information recording media of thickness different between them and made of a transparent plate, said converging element having an inner region near a center axis of the light beam and an outer region far from the center axis, said outer region having a plane optimized to converge the light beam transmitting said outer region onto a first optical information recording medium among the optical information recording media, said inner region having a plane optimized to converge the light beam transmitting said inner region onto another optical information recording medium having a larger thickness than the first one, wherein a phase of the light beam transmitting an innermost portion in the plane of said outer region is shifted relative to that of the light beam transmitting an outermost portion in the plane of said inner region.

2. The converging element according to claim 1, wherein said converging element is an object lens which comprises said inner region and said outer region.

3. The converging element according to claim 2, wherein when the light beam is converged on the first optical information recording medium, and wave-front

aberration satisfies that

total amplitude of aberration ≥ 20 mλ (rms),

and

fifth spherical aberration ≤ 20 mλ (rms).

4. The element according to claim 3, wherein when the light beam is converged on the first optical information recording medium, and the wave-front aberration satisfies that

seventh spherical aberration ≤ 30 mλ (rms).

5. The converging element according to one of claims 2 to 4, wherein the plane of said inner region is the plane optimized to converge the light beam transmitting said inner region onto the another optical information recording medium having a smaller thickness than a second optical information recording medium among the optical information recording media.

6. The converging element according to claim 5, wherein a direction of the shift of the phase of the light beam transmitting the innermost portion of the plane of said outer region is forward direction.

7. The converging element according to claim 1, wherein numerical aperture, NA, of the plane of said inner region and NA of the entire aperture has a following relationship that

0.7 * NA of entire aperture ≤ NA of inner region ≤ 0.8

* NA of entire aperture,

and phase shift of the light beam transmitting the innermost portion of the plane of said outer region to that of the light beam transmitting the outermost portion of the plane of said inner region has a value between 50 and 150 degrees.

8. The converging element according to one of claims 1 to 7, wherein said converging element is optimized to converge the light beam onto an information recording medium having a thickness of the inner region equal to or smaller than t1*0.6 wherein t1 denotes thickness of a plane of a second information recording medium among the optical information recording media.

9. The converging element according to one of claims 2 to 8, wherein the innermost portion of the plane of said outer region and the outermost portion of the plane of said inner region construct a smooth line.

10. The converging element according to claim 1, wherein said element comprises a lens which converges the light beam from the light source onto an optical information recording medium and an optical plate element to be cooperated therewith;

wherein said lens comprises a first inner region near a center axis of the light beam and a first outer region far from the center axis, said first outer region

having a plane optimized to converge the light beam transmitting said first outer region onto the first optical information recording medium, said first inner region having a plane optimized to converge the light beam transmitting said first inner region onto the another optical information recording medium having a larger thickness than the first optical information recording medium;

wherein said optical plate element comprises a second inner region and a second outer region divided from the second inner region with an optical step, said second inner region and said outer region are arranged such that the light beam transmitting said first outer region transmits said second outer region while the light beam transmitting said first inner region transmits said second inner region when said optical plate element is cooperated with said lens.

11. The converging element according to claim 10, wherein thickness of said second inner region of said optical plate element is different from that of said second outer region thereof.

12. The converging element according to claim 10, wherein said second inner region of said optical plate element is made of a dielectric material different from that of said second outer region.

13. The converging element according to claim 1, wherein said converging element comprises a lens which converges the light beam from the light source onto an optical information recording medium and an optical plate element arranged in an optical path between the light source and said lens;

wherein said lens has a plane optimized to converge the light beam transmitting said lens onto the first optical information recording medium when said optical plate element is not cooperated;

wherein said lens comprises an inner region near the center axis of the light beam and an outer region far from the center axis, said inner region and said outer region being divided from each other with an optical step, said lens having a flat plane in said outer region, said lens having a plane in said inner region optimized to converge the light beam transmitting said inner region onto the optical information recording medium having a larger thickness than the first one when said lens is cooperated with said optical plate element.

14. An optical head comprising:

a light source which generates a light beam;

a converging element which converges a light beam from said light source onto each of at least two types of optical information recording media made of a transparent

plate of different thicknesses; and

a photodetector which receives a light reflected from the each of the optical information recording media to convert it to an electric signal;

wherein said converging element comprises an inner region near a center axis of the light beam and an outer region far from the center axis, said outer region having a plane optimized to converge the light beam transmitting said outer region onto a first optical information recording medium among the optical information recording media, said inner region having a plane optimized to converge the light beam transmitting said inner region onto another optical information recording medium having a larger thickness than the first one, and a phase of the light beam transmitting an innermost portion in the plane of said outer region is shifted relative to that of the light beam transmitting an outermost portion of the plane of said inner region.

15. The optical head according to claim 14, wherein said light source generates light beams of two different wavelengths.

16. The optical head according to claim 14, wherein said light source generates a light beam of one wavelength.

17. The optical head according to claim 1, wherein said converging element is an object lens which comprises

the inner region and the outer region.

18. The optical head according to claim 17, wherein when the light beam is converged onto the first optical information recording medium, and wave-front aberration satisfies that

total amount of aberration ≥ 20 mλ (rms),

and

fifth spherical aberration ≤ 20 mλ (rms).

19. The optical head according to claim 18, wherein when the light beam is converged onto the first optical information recording medium, and wave-front aberration satisfies that

seventh spherical aberration ≤ 30 mλ (rms).

20. The optical head according to one of claims 14 to 19, wherein the plane of said inner region has the plane optimized to converge the light beam transmitting said inner region onto the another optical information recording medium having a smaller thickness than a second optical information recording medium among the optical information recording media.

21. The optical head according to claim 20, wherein a direction of the shift of the phase of the light beam transmitting the innermost portion of the plane of said outer region is forward direction.

22. The optical head according to claim 21, wherein

numerical aperture, NA, of the plane of said inner region and NA of the entire aperture has a following relationship that

$$0.7 * \text{NA of entire aperture} \leq \text{NA of inner region} \leq 0.8 * \text{NA of entire aperture},$$

and phase shift of the light beam transmitting the innermost portion of the plane of said outer region to that of the light beam transmitting the outermost portion of the plane of said inner region has a value between 50 and 150 degrees.

23. The optical head according to one of claims 14 to 22, wherein said converging element is optimized to converge the light beam onto an information recording medium having a thickness of the inner region equal to or smaller than $t1*0.6$ wherein $t1$ denotes thickness of a plane of a second information recording medium among the optical information recording media.

24. The optical head according to one of claims 14 to 23, wherein at least two of said photodetector are provided for said at least two optical recording information media of different thicknesses.

25. The optical head according to claim 1, wherein said element comprises a lens which converges the light beam from the light source onto an optical information recording medium and an optical plate element to be

cooperated therewith;

wherein said lens comprises an inner region near a center axis of the light beam and an outer region far from the center axis, said outer region having the plane optimized to converge the light beam transmitting said outer region onto the first optical information recording medium, said inner region having the plane optimized to converge the light beam transmitting said inner region onto the another optical information recording medium having a larger thickness than the first one;

wherein said optical plate element comprises an inner portion and an outer portion divided from the inner portion with an optical step, said inner and outer portions are arranged in cooperation with said lens such that the light beam transmitting said outer region of said lens transmits said outer portion and the light beam transmitting said inner region of said lens transmits said inner portion.

26. The optical head according to claim 25, wherein said light source generates light beams of two wavelengths, and said lens has a plane in said outer region optimized to converge the light beam of a first wavelength in the two wavelengths transmitting said outer region onto the first optical information recording medium and has another plane in said inner region optimized to converge the light beam

of a second wavelength different from the first one transmitting said inner region onto the another optical information recording medium having a larger thickness than the first one when said lens is cooperated with said optical plate element.

27. The optical head according to claim 25 or 26, wherein said optical plate element and said lens are held by a movable member having a driver means which moves it in focus and tracking directions for said lens, and said optical plate element and said lens are arranged to keep dynamical balance relative to a center of gravity of said movable member.

28. The optical head according to claim 14, wherein said converging element comprises a lens which converges the light beam from the light source onto an optical information recording medium and an optical plate element arranged in an optical path between said light source and said lens;

wherein said lens has the plane optimized to converge the light beam transmitting said lens onto the first optical information recording medium when said optical plate element is not cooperated therewith, and said optical plate element comprises an inner portion near a center axis of the light beam and an outer portion far from the center axis, said inner portion and said outer portion

being divided from each other with an optical step, said lens having a flat plane in said outer region, said lens having a plane in said inner region optimized to converge the light beam transmitting said inner region onto the another optical information recording medium having a larger thickness than the first one when said lens is cooperated with said optical plate element.

29. The optical head according to claim 27, wherein said light source generates light beams of two wavelengths, and said lens has the plane in said inner region optimized to converge the light beam of a second wavelength different from a first one generated by said light source and transmitting said inner region onto the another optical information recording medium having a larger thickness than the first one.

30. An optical information recording and reproducing apparatus comprising:

a light source which generates a light beam;

a converging element which converges a light beam from said light source onto each of at least two types of optical information recording media of different thicknesses and made of a transparent plate;

a photodetector which receives a light reflected from the each of the optical information recording media to convert it to an electric signal; and

a signal processor which distinguishes the type of optical information recording medium and reads information selectively from the electric signal;

wherein said converging element comprises an inner region near a center axis of the light beam and an outer region far from the center axis, said outer region having a plane optimized to converge the light beam transmitting said outer region onto a first optical information recording medium among the optical information recording media, said inner region having a plane optimized to converge the light beam transmitting said inner region onto another optical information recording medium having a larger thickness than the first one, and a phase of the light beam transmitting an innermost portion in the plane of said outer region is shifted relative to that of the light beam transmitting an outermost portion of the plane of said inner region.

31. The apparatus according to claim 30, wherein said converging element comprises an object lens which comprises the inner region and the outer region.

32. The apparatus according to claim 31, wherein when the light beam is converged onto the first optical information recording medium, and wave-front aberration satisfies that

$$\text{total amount of aberration} \geq 20\ m\lambda\ \text{(rms)},$$

and

fifth spherical aberration ≤ 20 mλ (rms).

33. The apparatus according to claim 32, wherein when the light beam is converged onto the first optical information recording medium, and wave-front aberration satisfies that

seventh spherical aberration ≤ 30 mλ (rms).

34. The apparatus according to one of claims 31 to 33, wherein the plane of said inner region of said converging element has the plane optimized to converge the light beam transmitting said inner region onto the first optical information recording medium having a smaller thickness than a second optical information recording medium among the optical information recording media.

35. The apparatus according to claim 20, wherein a direction of the shift of the phase of the light beam transmitting the innermost portion of the plane of said outer region is forward direction.

36. The apparatus according to claim 35, wherein numerical aperture, NA, of the plane of said inner region and NA of the entire aperture has a following relationship that

0.7 * NA of entire aperture ≤ NA of inner region ≤ 0.8 * NA of entire aperture,

and phase shift of the light beam transmitting the

innermost portion of the plane of said outer region to that of the light beam transmitting the outermost portion of the plane of said inner region has a value between 50 and 150 degrees.

37. The apparatus according to one of claims 31 to 36, wherein said converging element is optimized to converge the light beam onto an information recording medium having a thickness of the inner region equal to or smaller than t1*0.6 wherein t1 denotes thickness of a plane of a second information recording medium among the optical information recording media.

38. The apparatus according to one of claims 31 to 37, wherein said photodetector is provided for each of the optical recording information media of different thicknesses.

39. The apparatus according to claim 30, wherein said element comprises a lens which converges the light beam from the light source onto an optical information recording medium and an optical plate element to be cooperated therewith;

wherein said lens comprises a first inner portion near a center axis of the light beam and a first outer portion far from the center axis, said first outer portion having a plane optimized to converge the light beam transmitting said first outer portion onto the first

optical information recording medium, said first inner portion having a plane optimized to converge the light beam transmitting said first inner portion onto the another optical information recording medium having a larger thickness than the first one;

wherein said optical plate element comprises a second inner portion and a second outer portion divided from the second inner portion with an optical step, said second inner and outer portions are arranged such that the light beam transmitting said first outer portion transmits said second outer portion while the light beam transmitting said first inner portion transmits said second inner portion when said optical plate element is cooperated with said lens.

40. The apparatus according to claim 39, wherein said optical plate element and said lens are held by a movable member having a driver means which moves it in focus and tracking directions for said lens, and said optical plate element and said lens are arranged to keep dynamical balance relative to a center of gravity of said movable member.

41. The apparatus according to claim 30, wherein said converging element comprises a lens which converges the light beam from the light source onto an optical information recording medium and an optical plate element

arranged in an optical path between the light source and said lens,

wherein said lens has the plane optimized to converge the light beam transmitting said lens onto the first optical information recording medium when said optical plate element is not used;

wherein said optical plate element comprises an inner region near the center axis of the light beam and an outer region far from the center axis, said inner region and said outer region being divided from each other with an optical step, said lens having a flat plane in said outer region, said lens having a plane in said inner region optimized to converge the light beam transmitting said inner region onto the another optical information recording medium having a larger thickness than the first one when said lens is cooperated with said optical plate element.

42. The apparatus according to claim 41, wherein said light source generates light beams of two wavelengths, and said lens has a plane in said inner region optimized to converge the light beam of a second wavelength different from a first one generated by said light source and transmitting said inner region onto the another optical information recording medium having a larger thickness than the first one.

43. A method of recording and reproducing information

to and from an optical information recording medium, comprising the steps of:

generating a light beam by a light source; and

converging the light beam onto the optical information recording medium;

wherein wave-front aberration of the light beam on the optical information recording medium satisfies that

total amount of aberration $\geq$ 20 mλ (rms),

and

fifth spherical aberration $\leq$ 20 mλ (rms).

44. The method according to claim 43, wherein when the light beam is converged onto the first optical information recording medium, and the wave-front aberration satisfies that

seventh spherical aberration $\leq$ 30 mλ (rms).

45. An optical head which converges a light beam from a light source onto each of first and second optical information recording media having different thicknesses from each other comprising:

said light source which generates a light beam to be converged on the first optical information recording medium and another light beam to be converged on the second optical information recording medium;

a converging element comprising an inner region near a center axis of the light beam and an outer region

far from the center axis, said outer region having a plane optimized to converge the light beam transmitting said outer region onto a first optical information recording medium among the optical information recording media, said inner region having a plane optimized to converge the light beam transmitting said inner region onto another optical information recording medium having a larger thickness than the first one, wherein a phase of the light beam transmitting an innermost portion in the plane of said outer region is shifted relative to that of the light beam transmitting an outermost portion of the plane of said inner region; and

a photodetector which receives a light reflected from the optical information recording medium to convert it to an electric signal;

wherein distance L1 from a first one of said light sources to said converging element and distance L2 from a second one of said light sources to said converging element satisfies a following relationship:

$$0.8 * L1 < L2 < 0.95 * L1.$$

46. The optical head according to claim 45, wherein said light source comprises a first light emitter which generates the light beam to be converged onto the first optical information recording medium and a second light emitter which generates the light beam to be converged onto

the second optical information recording medium, and said photodetector comprising a first photodetector which receives the light beam reflected from the first optical information recording medium and a second photodetector which receives the light beam reflected from the second optical information recording medium, wherein said first and second light emitters are integrated as one body and said first and second photodetectors are integrated as one body.

47. An optical recording and reproducing apparatus comprising:

an optical head which converges a light beam from a light source onto each of first and second optical information recording media having transparent plates of different thicknesses; and

a controller which processes reproduction signals and control signals selectively from electrical signals from said optical head and generates reproduction signals;

wherein said optical head comprises:

a light source which generates a light beam to be converged on the first optical information recording medium and another light beam to be converged on the second optical information recording medium;

a converging element comprising an inner region near a center axis of the light beam and an outer region

far from the center axis, said outer region having a plane optimized to converge the light beam transmitting said outer region onto a first optical information recording medium among the optical information recording media, said inner region having a plane optimized to converge the light beam transmitting said inner region onto another optical information recording medium having a larger thickness than the first one, wherein a phase of the light beam transmitting an innermost portion in the plane of said outer region is shifted relative to that of the light beam transmitting an outermost portion of the plane of said inner region; and

a photodetector which receives a light reflected from the optical information recording medium to convert it to an electric signal;

wherein distance L1 from a first one of said light sources to said converging element and distance L2 from a second one of said light sources to said converging element satisfies a following relationship:

$$0.8 * L1 < L2 < 0.95 * L1.$$

48. An optical head comprising:

a light source which generates light beams of second and third wavelengths;

a converging element comprising a central region having numerical aperture of NA1 and an outer region having

numerical aperture between NA1 and NA2, said outer region being formed to decrease aberration when light is converged through a transparent flat plate of thickness of t1, said central region being formed to decrease aberration when light is converged through a transparent flat plate of thickness between t2 and 0.7 * t2; and

an optical system which converges the light beam of the first wavelength through said converging element onto a first information plane of the first optical information recording medium of thickness t1, converges the light beam of the second wavelength through said converging element onto a second information plane of the second optical information recording medium of thickness t2 larger than t1 and guides the light beam reflected from the first or second information plane to a photodetector;

wherein an optical element is provided in said optical system, said optical element preventing incidence of the reflected light of the first wavelength in a ring region in correspondence to numerical aperture of said converging element between NA1 and 0.7 * NA1.

49. The optical head according to claim 48, wherein said optical element comprises a light-shielding member which shields the reflected light of the first wavelength in the ring region.

50. The optical head according to claim 49, wherein

said optical element comprises a polarizing hologram diffracting the reflected light of the first wavelength in the ring region.

51. The optical head according to claim 48, wherein said photodetector comprises a first sensor and a second sensor, and said optical system converges the light beam of the first wavelength through said converging element onto a first information plane in the first optical information recording medium of thickness t1, converges the light beam of the second wavelength through said converging element onto a second information plane in the second optical information recording medium of thickness t2 larger than t1, guides the light beam reflected from the first information plane to said first sensor and guides the light beam reflected from the second information plane to said second sensor.

52. The optical head according to claim 50, wherein said photodetector comprises a first sensor and a second sensor, and said optical system converges the light beam of the first wavelength through said converging element onto a first information plane of the first optical information recording medium of thickness t1, converges the light beam of the second wavelength through said converging element onto a second information plane of the second optical information recording medium of thickness t2 larger than t1,

guides the light beam reflected from the first information plane to said first sensor and guides the light beam reflected from the second information plane to said second sensor.

53. The optical head according to claim 52, wherein said polarizing hologram diffracts the reflected light of the first wavelength to form light needed for reproduction and control.

54. The optical head according to one of claims 50, 51 and 52, wherein a wavelength plate is provided between said converging element and said polarizing hologram, wherein said wavelength plate makes a polarizing plane of the reflected light of the first wavelength substantially perpendicular to that of the light beam of the first wavelength converging onto the first information plane and makes a polarizing plane of the reflected light of the second wavelength substantially in the same direction as that of the light beam of the second wavelength converging onto the second information plane.

55. The optical head according to one of claims 48 to 54, wherein the central region of said converging element is designed to decrease aberration for a transparent flat plate of thickness between 0.84 and 1.2 mm when the first optical information recording medium has thickness t1 of 0.6 mm and the second optical information recording medium

has thickness t2 of 1.2 mm.

56. The optical head according to one of claims 48 to 54, wherein the numerical aperture NA1 of the central region of said converging element is 0.45 and NA2 of the outer region is 0.6 for the first wavelength is 630 to 680 nm and for the second wavelength is 760 to 840 nm.

57. An optical recording and reproducing apparatus comprising:

an optical head which converges a light beam from a light source onto each of first and second optical information recording media having transparent plates of different thicknesses; and

a controller which processes reproduction signals and control signals selectively from electrical signals from said optical head and generates reproduction signals;

wherein said optical head comprises:

a light source which generates light beams of first and second wavelengths;

a converging element comprising a central region having numerical aperture of NA1 and an outer region having numerical aperture between NA1 and NA2, said outer region being formed to decrease aberration when light is converged through a transparent flat plate of thickness of t1, said central region being formed to decrease aberration when light is converged through a transparent flat plate of

thickness between t2 and 0.7 * t2; and

an optical system which converges the light beam of the first wavelength through said converging element onto a first information plane in the first optical information recording medium of thickness t1, converges the light beam of the second wavelength through said converging element onto a second information plane in the second optical information recording medium of thickness t2 larger than t1 and guides the light beam reflected from the first or second information plane to a photodetector;

wherein an optical element is provided in said optical system, said optical element prevents incidence of the reflected light of the first wavelength in a ring region in correspondence to numerical aperture of said converging element between NA1 and 0.7 * NA1.